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HOW MANY ANIMAL SPECIES REMAIN TO BE DISCOVERED?

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ABSTRACT: Although it is impossible to count the number of organisms which remain undiscovered, and which, according to some, might not even exist, the study of the past discovery of new species in various zoological groups can throw some light on their numerical importance within each group, and on the rate at which new species have been described. It is then possible to estimate the number of species which will be discovered in the future. A historical study of those discoveries which led to reassessments of zoological classification indicates that the highest hopes in this regard may be entertained in *all* invertebrate phyla, and even in marine vertebrates. Cryptozoology, by its very nature, focuses on unknown species of large to moderate size. Its best prospects should be among some rare groups of marine invertebrates, as well as in marine vertebrates. Even though the probabilities of making discoveries of truly revolutionary impact on systematic zoology have become extremely low for land vertebrates, we should nevertheless continue to expect the regular discovery, each year, of numerous presently unknown species, to be classified within groups already known, even if only in the fossil record.

INTRODUCTION

It is obvious even to the layman that there is a much better chance of discovering a hitherto unknown insect than finding a mammal, a bird, or a reptile which has not yet been scientifically described. But what exactly are the respective chances of finding today new species in the various zoological categories? This is what we shall attempt to answer below.

CLASSIFICATION BEFORE CENSUS

To gain some idea of the number of animal species yet to be discovered, one must identify and count, in each of the major zoological groups, those species which *have* been discovered over the centuries; in this way, one may

measure the rate at which new species have been found. It is first necessary, however, to find a method of classifying all of these species in some convenient way, reflecting, if possible, the natural organization of the animal world.

In his *Systema naturae,* where he introduced a classification of living beings which developed into the present taxonomic system (the science of classification, and the rules on which it is based), Carl von Linné (1758) distinguished within the animal kingdom only six categories, with still rather imprecise boundaries: the mammals, the birds, the amphibians (which included the reptiles, and even some fish), the fish, the insects (which included all articulated animals: today's arthropods), and, finally, the worms, a veritable hodge-podge which included all soft-bodied animals lacking the jointed armor of the arthropods and the inner skeleton of the vertebrates.

Each one of these classes was subdivided into a certain number of orders, each order, in turn, into families, families into genera, these genera into species, and, finally, the species into varieties.

From the beginning of the Nineteenth Century, some of the six Linnean classes began, after more careful work, to be divided into more classes. The painstaking analysis of a meticulous observer such as Lamarck soon resulted in twelve classes of animals (1806), and later (1809) fourteen. The old classes of worms and insects—animals without backbones—literally exploded: they now came to include molluscs; annelids (aquatic and terrestrial worms); intestinal worms; cirripedians (such as barnacles or sea-acorns); crustaceans; arachnids; insects; radiates (organisms with radial symmetry such as starfishes); polyps; and infusorians.

At the same time, Cuvier (1817) was trying to reduce this proliferation of classes to four general forms, four groups with distinctly different organizations: the vertebrates, the molluscs, the articulates and, at the bottom of the scale, the radiates, in which were included the zoophytes, plant-like animals of equivocal appearance. Cuvier's fundamental types were to evolve into what we now call phyla, major groups of organisms whose common ancestry is evident to evolutionary biologists.

With the progress of anatomical knowledge, the four fundamental phyla, each one gathering an increasing number of classes, also became subject to a gradual division process. Today, we have at least twenty phyla, divided into seventy five classes, without even counting those which have become extinct during past geological ages.

A Modern Classification of the Animal Kingdom

The reader would obtain a good appreciation of the richness and diversity of the animal world from the outline of a recently proposed zoological classification. This classification, neither too revolutionary nor outmoded, is based on that presented by L. H. Hyman, an American invertebrate zoologist, in the 1962 edition of the *Encyclopedia Britannica.* One must

admit that there exist many others: as many, indeed, as there are classifiers. They all agree on essential points, however, and differ only in the way in which they group or distinguish between various branches of invertebrates, as well as by the position which they assign to particularly obscure groups of ambiguous invertebrates such as tardigrades (bear animalcules, or water bears), onychophorans (*Peripatus* or worm insects), and pentastomides (or linguatulids). As knowledge progresses, classifications are in a state of perpetual re-arrangement. To quote French zoologist Pierre-Paul Grassé (1968): "It would be a gross misinterpretation to believe that the present classification is definitive, and that it represents only natural lineages and the affinities between them."

Here is, then, a list of those phyla which are most commonly recognized today. Most of them are quite unfamiliar to the layman, who would consider them to be of interest to only a few eccentric specialists:

1) *Protozoa,* one-celled animals;
2) *Mesozoa,* minute parasites of some sea worms or of the kidneys of some cephalopods; these organisms are reduced to a central cell enclosed in a single layer of surface cells;
3) *Porifera,* or sponges;
4) *Cnidaria,* or common coelenterates (hydrae, jellyfish, sea anemones, and corals);
5) *Ctenophora,* or comb-jellies, coelenterates with rows of ciliated plates;
6) *Platyhelminthes,* or flat worms without an anus. They are free living (planaria) or parasitic (flukes and tapeworms);
7) *Rhynchocoela or Nemertina,* ribbon-like worms with both anus and protrudible proboscis;
8) *Acanthocephala,* spiny-headed parasitical worms;
9) *Aschelmintha,* a vast assemblage of diverse worms, the best known of which are the rotifers, with ciliated wheels, the nematodes, or roundworms, and the gordian worms;
10) *Entoprocta,* aberrant worms (formerly called vermidians, or wormlike; it is in a phylum of that name that Delage and Hérouard [1897] put all unarticulated invertebrates which they could not fit elsewhere.), whose mouth and anus are close together, and which are surrounded by a graceful crown of ciliated tentacles;
11) *Phoronida,* other vermidians with only the mouth crowned with cilia;
12) *Ectoprocta,* more vermidians, similarly crowned, but forming vast colonies (they were formerly in the Bryozoa, i.e., "moss animals");
13) *Brachiopoda,* or "lamp shells," vermidians enclosed like oysters in a bivalve shell;
14) *Mollusca,* from chitons to octopuses and squids, snails, clams and tooth shells;
15) *Sipunculida,* wormlike, with introversible mouth;

16) *Annelida,* worms with long jointed bodies, including those with many bristles and living in the sea (polychetes), the earthworms, and the leeches;
17) *Arthropoda,* or animals with jointed armor, the best known classes of which are the crustaceans, the arachnids (including myriapods, i.e., centipedes and millipedes) and the insects;
18) *Echinodermata*, sea-urchins, starfish, serpent stars, sea-lilies and sea-cucumbers;
19) *Chaetognatha,* or arrow worms, wormlike sea animals with grasping spines, but without either tubular cord or gill slits;
20) *Pogonophora,* other wormlike animals from the abyssal depths of the ocean, enclosed in a transparent mucous tube;
21) *Hemichordata or Stomochordata,* non-transparent vermidians with pharyngeal gill slits and a primitive nerve chord in the mouth;
22) *Chordata,* animals which in their adult state have either gill slits, a vertebral column (sometimes reduced to a dorsal nerve chord) or both; this, of course, is the phylum to which humans belong, together with other vertebrates, whether they be mammals, birds, reptiles, or amphibians.

The Small Fry Escape Cryptozoology

The layman dreaming of zoological adventures, the amateur naturalist, and indeed all those who may be keen to explore the animal world but have not delved into the many detours and labyrinths of the zoological sciences, may rest assured: they may immediately forget this unappealing inventory, this rather boring list of barbaric names. Within the scope of cryptozoology, the science of animals yet to be discovered, there is no need to keep track of minuscule specimens. Each year brings an impressive harvest of small new life forms, a fact which surprises no one (Anonymous 1952). All that can be done to discover those new organisms is to continue, as in the past, to harvest them blindly, relying mostly on chance. It is, of course, possible to improve the instruments by which they may be captured, or to organize the search for new species on a more systematic, broader, and more energetic basis. This is, indeed, one of the traditional aims of zoology. One may not expect in those cases, however, to orient the search for certain species in the hope of hastening their discovery, as is the essential aim of cryptozoological work, where some notion of a particular species' existence is reported but not fully documented.

This cryptozoological aim may be realized only through the stubborn collection of a rich fund of eye-witness reports, indigenous lore and traditions, tracks, and other material evidence, and through the elaboration of circumstantial evidence.

For an unknown animal to be reported, or for it to bring attention to itself, it is necessary that it should be *highly visible,* and hence be of an *appreciable size.* This concept is, of course, subjective and rather relative, and should perhaps be supplemented by that of *abnormal size* within a certain group. Few except professionals would consider reporting unexpected observations of a bird of the size of a sparrow or of a fish of the length of a minnow; however all would marvel at an ant as large as a vole, or at a spider spanning a long-playing record. In fact, those elusive animals with which we are concerned, and around which legends are soon woven, permitting them to be sought and tracked down, are those which are characterized by some trait which is truly singular, unexpected, paradoxical, striking, emotionally upsetting, and thus capable of mythification. Even if that trait is not necessarily linked to an impressive size, it remains that a minimum size is essential.

Thus, cryptozoology generally does not deal with most of the phyla listed above. There are a few rare exceptions: a gigantic medusa, the lion's mane jellyfish, whose gelatinous bell has a diameter of nearly three meters, and whose trailing tentacles hang down nearly 40 meters; a marine worm, *Lineus longissimus,* no thicker than one's thumb, but reaching up to twenty meters in length; a few gigantic marine molluscs, mostly octopuses and squids; some sea scorpions of ages past which exceeded the size of a man; and finally some very rare present-day crustaceans such as the Japanese stilt-crab. Generally, however, most animals of medium to large size are, and have always been, to our knowledge, members of the last phylum, the chordates, and, further, of a single one of its sub-phyla. These sub-phyla are three in number: the Urochordata, or tunicates, of which the best known representative is an edible sea-squirt, the "Vioulet" or "Biju" of the Provencal fish markets; the Cephalochordata or Acrania (without skull), of which the famous *Amphioxus* (now in the genus *Branchiostoma*), a transparent marine dart, is held to be very close to the ancestral type of the vertebrates, but which does not exceed half a dozen centimeters in length; and the Vertebrata proper, which are of great interest to cryptozoology.

Thus, except in the marine area, where we shall have to take into account the exceptional but nevertheless possible existence of giant invertebrates most probably belonging to one of four definite phyla (Cnidaria, Nemertina, Mollusca, and Arthropoda), those hitherto unknown animals whose existence and classification one might hope to determine by the methods of cryptozoology are almost certainly members of one of the following eight classes which make up the sub-phylum Vertebrata:

a) *Agnatha,* jawless fish, represented nowadays by lampreys, hagfish, and slime eels;
b) *Placodermi,* mainly armored fishes of the Devonian period, but possibly also including the chimeras, most often included in the next class;
c) *Chondrichthyes,* cartilaginous fishes, including sharks, skates, and rays;
d) *Osteichthyes,* bony fishes (i.e., all other fishes);
e) *Amphibia,* most of which lead a double life, first aquatic, then terrestrial;

f) *Reptilia,* cold-blooded "crawlers," mainly in tropical zones;
g) *Aves,* warm-blooded, feathered flyers;
h) *Mammalia,* with hair and mammary glands.

Normally, each time a new animal is collected or captured, it is rather easy for a trained zoologist to determine, after a brief examination (often a mere glance suffices), which phylum of the animal kingdom it belongs to. For parasitic worms, or for wormlike sea creatures, some difficulties of identification may arise, requiring special expertise. If the unknown creature is a member of the sub-phylum Vertebrata, however, it is almost childs-play to recognize the class into which it should be placed. Specialists of the fundamental classes of vertebrates—ichthyologists, herpetologists, ornithologists and mammalogists—can usually recognize at a glance the order and often the family to which a given specimen belongs. Determination of the genus, and especially of the species, usually requires a more detailed study.

Where to put the Unclassifiables?

It soon became apparent that there exist "deviant" animals, which do not correspond to the definition of their name: exclusively aquatic amphibians; reptiles which, far from crawling, run, jump and even fly; birds which cannot fly; and mammals without real breasts. Such "deviants" usually exhibit most of the *other* traits of their class, however, and it is usually easy to recognize their true nature. Might it not happen, though, that one would not know exactly where to place an unknown animal because it does not fit into *any* of the known groups?

This could well happen, and has actually occurred often in the past. There was a time, not so long ago, when it was not even certain in which kingdom to place certain creatures. Up to the Eighteenth Century, coral was thought to be a petrified marine tree, intermediate between the plant and the mineral kingdoms. Such a double nature was also attributed to what were appropriately named zoophytes, such as sponges and sea anemones, of which it was not known, in the words of Pierre Belon (1555) "whether they were plants or animals."

More careful studies have, of course, dissipated such superficial ambiguities. For centuries now, whenever a new animal has appeared onto the zoological stage, it has always been possible to fit it into one or another of the known phyla, or even classes, because the limits of these broad categories long remained poorly defined. The existence of catch-all categories, such as those of worms, or vermidians, was also of providential usefulness in this respect. However, even after the diagnosis of fundamental categories had been rigorously established, classification problems still occurred from time to time, and it was sometimes necessary to create new groups to accommodate the unclassifiables. The unearthing of fossil forms has often required

the creation of broad new categories. And sometimes, when a modern form was discovered, it so happened that it could be placed within an established group whose other representatives were known *only* from the fossil record. Such animals have been called "living fossils," an expression invented, perhaps in jest, by Darwin himself, and which has been much abused as it really has no objective meaning.

As the exploration of our world has progressed, the number of new forms being discovered has gradually diminished, whether they be true fossils or "survivors" from the past. More importantly, the number of new classes created to accommodate these new creatures has also gradually decreased over time. Nowadays, the description of new species is a routine matter, and that of new genera usually equally unexciting. Much more rarely, one may have to introduce a new family. Innovation at the level of the higher categories—orders, classes, phyla—has become, as one would expect, quite exceptional.

Nevertheless, however improbable this may appear, major reclassifications of animals are still sometimes necessary in order to accommodate completely unexpected new life forms.

Upsetting Discoveries Come from the Sea

Limiting ourselves to the present century, we shall briefly review the most dramatic revolutions which occurred in the classification of animals. The order which we shall follow is that of the phyla listed above.

In 1959, a completely new type, requiring the creation of a new family, was added to the coelenterates of the phylum Cnidaria, when the British oceanographic vessel *Sarsia* brought up, from a depth of more than 3,000 meters in the Bay of Biscay, a plum-colored jellyfish trailing tentacles which, when fully extended, measured two meters from tip to tip. Viviparous, although reproducing asexually, this animal was baptized *Stygiomedusa fabulosa*: the fabulous jellyfish from the deep.

It is also through the exploration of the abyssal depths that we have considerably enriched out knowledge of the phylum Mollusca.

In 1903, a black ciliated octopus which appeared common at great depths, but with *ten* tentacles rather like a cuttlefish or a squid, was described by the German scientist Carl Chun, and given the impressive name *Vampyroteuthis infernalis*: the devilish vampire-squid. After an in-depth study of this ambiguous monster, Grace Evelyn Pickford created the new order Vampyromorpha for it in 1946.

An even more sensational incident occurred in the world of molluscs. Their classification was completely disrupted in 1940, following a reinterpretation by N. Odhner of a small cap-shaped fossil shell, long known under the name *Pilina*: a new class, the Monoplacophora, had to be created for this organism. One may well imagine the surprise and the emotion of the Danish specialist Henning M. Lemche when he recognized, in a haul of

specimens dredged by the *Galathea* in 1952 in the Pacific off Costa Rica, a living specimen of this class, thought to be extinct for 350 to 400 million years. He baptized it in 1957 with the name of *Neopilina galathea.* Since then, three new species of this genus have been discovered.

The phylum Arthropoda is that to which the greatest number of important additions have been made in this century, among the crustaceans, as well as insects, and even recently in the arachnids.

Entire orders had to be added to the class Insecta: the Protura, in 1907, minuscule insects, without either wings or antennae, which do not even go through metamorphosis; the Zoraptera, in 1913, which includes about twenty small tropical species; the Notoptera, in 1915, fairly large insects which live in the snow of high mountains in Japan and North America, at a temperature close to freezing. Quite recently, in 1978, a strange male cricket was collected in Queensland, Australia; it combined the characteristic traits of three different families of Orthoptera, and a new family will probably have to be created for it. Until more specimens are caught, and a more appropriate and pompous scientific name is chosen, this cricket goes under the nickname "Cooloola Monster."

In 1983, the discovery in a tropical rain forest of the smallest known spider, *Micromygale diblemma,* led to the creation of a new sub-family of arachnids by its scientific sponsor, Norman I. Platnick. One must admit that this creature is completely abnormal: not only does it lack lungs, breathing directly through its skin, but it has only two eyes, which is truly monstrous in a group where everyone has from six to eight!

It is undoubtedly among the aquatic arthropods, particularly the crustaceans, that the most radical taxonomic changes have occurred, and invariably continue to happen.

Among the peracarids, a fossil subclass, a new order, the Thermosbaenacea, had to be introduced in 1927 by Theodore Monod, following the capture by L.-G. Seurat, in the Tunisian hot spring of Hel Hamma, of specimens of a unique species which Monod had named *Thermosbaena mirabilis* in 1924. Nine other species of this well-hidden group have subsequently been discovered, all in the Mediterranean area, and as far as Texas in the New World. They had to be accommodated into three new genera: *Monodella,* described in 1949 by Ruffo, which now contains seven species, and the genera *Halosbaena* and *Limnosbaena,* described by Stock in 1976.

The sub-class of the minute mystacocarids was created only in 1943, following the discovery, in the interstitial waters of a sandy beach, of the first specimen of the genus *Derocheilocaris,* whose various species are now known the world over.

In 1957, another new sub-class, the cephalocarids, reminiscent of the trilobites of the Paleozoic Era, had to be created to include the genus *Hutchinsoniella,* the first specimens of which had been fished out by Howard L. Sanders two years earlier from the muddy bottom of Long Island Sound,

New York. That same year, the new order of Speleogriphacea was added to the crustaceans, following the collection of a completely unclassifiable species in the subterranean waters of a cave in Table Mountain, overlooking Cape Town, South Africa.

In 1975, two French scientists, Jacques Forest and Michèle de Saint-Laurent, recognized in a jar stored at the Smithsonian Institution a representative of the family Glypheidae, believed extinct since the Eocene. It had been marinating there for nearly seventy years, since it had been collected in 1908 by the oceanographic ship *Albatross* off the Philippines. In the spring of 1976, the same two scientists brought up a live specimen of this animal, named *Neoglyphea inopinata,* a presumed ancestor of crabs, shrimps, and lobsters.

The phylum Echinodermata has also experienced a revolution, without even the need to track down a new species. In 1962, the New Zealander H. Barraclough Fell announced that a relatively rare starfish from the Pacific coast of Mexico, *Platasterias latiradiata,* described by Gray in 1871, was really the last survivor of the fossil class Somasteroidia, believed extinct since the Ordovician, i.e., 400 million years ago.

A Completely New Phylum of Invertebrates and Many Important Fishes

Even more extraordinary, almost unthinkable, would be the discovery of a whole unknown phylum of the animal kingdom. But that is precisely what happened not very long ago.

This astounding revelation was the result of a gradual process. In 1914, Maurice Caullery had given the name *Siboglinum weberi* to a kind of thread-like and transparent worm dredged from abyssal muds by the Dutch oceanographic expedition ship *Siboga.* The French biologist described it prudently as "a new type of invertebrate," and tentatively classified it as an addendum to the phylum Stomochordata. Returning to it in 1944, he was of the opinion that its affinities were still imprecise. In the meantime, in 1933, the Russian P. V. Ushakov had described a similar creature, which he named *Lamellisabella zachsi,* as an unknown form of the polychete worms. A few years later, in 1937, the Swede K. E. Johansson carried out a careful histological study which cast doubt upon the validity of that interpretation. For the latter, the species in question justified the creation of a new class of worms: the Pogonophora, or "beard wearers." Then, in 1944, the Russian V. N. Beklemishev went further in suggesting that this class of "bearded worms" was really a distinct phylum, to be placed in the vicinity of the Stomochordata, as Caullery had brilliantly suspected. This interpretation has since been fully justified, mostly from the rich catches brought back from the oceanographic cruises of the Soviet oceanographic vessel *Vitiaz* (1949–58), and, to a lesser extent, by the Danish ship *Galathea* (1952).

Today, the phylum Pogonophora still includes a single class, which is now,

however, divided into two orders, containing five families, for a total of eleven different genera. Of the 43 known species, 37 have been described by the Soviet scientist Artemii Vassilievitch Ivanov, who has become the greatest specialist on this phylum, having written in 1960 a now-classic monograph on that subject. These pogonophorans literally swarm in the abyssal muds, forming masses resembling Chinese noodles. Their most remarkable feature is their complete lack of a digestive tube; they are the only multicellular organisms in the world without one. Zoologists are still speculating on just how they feed.

One will have noted that the revolutions which have occurred in the Twentieth Century in the classification of the animal kingdom have, so far, all been concerned with invertebrates. The most sensational, the most stupefying of all the zoological discoveries of our time is thus undoubtedly that of the coelacanth, *Latimeria chalumnae* in 1938. This fish, of the order Coelacanthiformes, a survivor from the Devonian, is the only living representative of the class Crossopterygia, believed extinct for the past 65 million years.

Among newly discovered fish, one whose novelty led to the creation of a systematically important group is a mid-depth stingray from South Africa, *Hexatrygon bickelli.* In contrast to all other batoid fishes (electric rays, guitar fishes, sawfishes, skates, stingrays, eagle-rays and devil-rays), this ray has six rather than five gill slits. When it was described, in 1980, it was placed in a new sub-order within the order Myliobatiformes: the Hexatrygonoidei.

Finally, a large shark, 4.5 meters long and more than 700 kilos in weight, caught quite fortuitously by a U.S. Navy ship off Hawaii in 1976, seems to justify by its aberrant anatomy the invention of a whole new family. This fish, known for years only under the nickname "Megamouth," for its extremely large mouth, has just been given the scientific name *Megachasma pelagios* (Taylor *et al.* 1983).

On Land: Much That Is New, But Nothing Revolutionary

To find readjustments of comparable magnitude in the classification of modern land vertebrates, one must go back to the last century.

In 1831 and 1842 John Edward Gray successively described under two different names, *Sphaenodon* and *Hatteria,* a cranium and a complete specimen of the same species of small New Zealand lizard. This animal was called tuatara, or "spiny-back," by the Maoris. A quarter of a century later, in 1867, Gray's assistant, Albert Günther, realized, while studying the anatomy of this unorthodox lizard, that it was really a survivor of the order Rhynchocephalia, known only from the fossil record, and more ancient than the dinosaurs.

The platypus, an extraordinary Australian animal with webbed feet and duck's bill first described by George Shaw in 1799, had first been placed by Johann Friedrich Blumenbach in the hodge-podge order of Edentata. Etienne Geoffroy-Saint-Hilaire, having noticed that this pseudo-otter, together with his pseudo-hedgehog cousin the echidna, the latter with a long beak and sporting a venomous spur, both had a cloaca, as reptiles and birds do, thought it more appropriate to set up especially for them the order of monotremes, "those with a single hole." These alleged mammals, which seemed to be lacking breasts and even appeared to be egg-layers, were too bizarre for Lamarck, who refused to include them with mammals, and who introduced for them an independent class which he called the Prototheria, or "first mammals." In 1834, Ducrotay de Blainville divided the class of mammals into three sub-classes: the Ornithodelphia (or monotremes), the Didelphia (or marsupials) and the Monodelphia (or placentals). It was only a half-century later that it was unequivocally determined that monotremes, those "unacceptable" mammals which nevertheless gave milk to their young, did indeed lay eggs. From now on, anything seemed possible in the animal kingdom.

In fact, it still happens, even nowadays, that a new family of terrestrial vertebrates must be introduced.

Thus, it was as recently as 1954 that it was noticed that the world's rarest lizard, a small earless monitor lizard from Borneo, *Lanthanotus borneensis,* discovered in 1878, exhibited so many of the traits of snakes that it had to be closely related to their common ancestor. It was thus placed, by itself, in a special family, the Lanthanotidae. Known until then only through a dozen mummified or preserved specimens, it was not until 1961 that a live specimen was captured and examined.

The family Craseonycteridae was created in 1974, following the discovery in Thailand of a very peculiar kind of bat, *Craseonycteris thonglongyai.* Some may state that this is really not so exciting, since it is the smallest known mammal. Its body, head included, hardly exceeds 3 centimeters, and it weighs no more than 2 grams; it has been nicknamed "the bumblebee bat." Nevertheless, this small animal represents a real significant zoological novelty.

All told, then, when one reviews the story of the major modifications of the zoological classification since the beginning of this century, one must recognize that they have been mostly concerned with unknown types of invertebrates, usually small and generally from the depths of the ocean, or from the equally dark waters of caves. What this means is that there is really very little chance of discovering, at least on land, large vertebrates *of a truly original body plan, and thus unknown even in the fossil record.*

This does not imply that we might not hope to discover such new forms in the oceans, or even in some inland waters. We shall see that one should expect to find, even on large land masses, numerous new species, some of

which may belong to unknown genera. It is certain that such species exist, and that some may be of appreciable size. I have already reviewed the numerous large land animals which had been discovered within the past 120 years (Heuvelmans 1955, 1958). Since such reviews, discoveries have continued to occur. It will suffice to recall a few: in 1965, of an unknown genus of cats, *Prionailurus iriotomensis,* in one of the Ryukyu Islands (Japan); in 1969, of a current Asiatic representative of the human Neanderthal wave, *Homo pongoides* (Heuvelmans 1969); and, in 1975, of the largest of the peccaries, *Catagonus wagneri,* known only as a Pleistocene fossil, and discovered live in Paraguay (Wetzel *et al.* 1975). Compared to those important discoveries made in the oceans or in caves in the past decades, these are really commonplace, at least from the perspective of systematic zoology, and one should perhaps be surprised that some of them have led to vehement and ongoing controversies.

Contrary to what one might be led to believe, one should not prejudge the size of animals still to be discovered, imagining that the smallest are necessarily those which can hide best. Paradoxically, in many groups, it is often the largest specimens which have been discovered last. The largest of the sharks, the whale shark, was discovered in 1828; the largest of the cephalopods, the giant squid, in 1856; the largest of the Procyonidae or raccoons, the giant panda, in 1869; the largest of the bears, the Kodiak bear, in 1899; a local race of the largest of rhinoceroses, Cotton's white rhino, in 1900; the largest of all apes (and the largest known non-human primate), the mountain gorilla, in 1901; the largest of the boars, the giant forest hog, in 1904; the largest of the lizards, the Komodo dragon, in 1912; and, as we noted above, the largest of the peccaries, the tagua, in 1975.

Have We Completed Only A Quarter of the Inventory?

It is now possible to calculate, with a fairly satisfactory degree of approximation, the number of new species which one should expect to discover in the decades to come. This calculation is based on the number of species already known.

We do not know, of course, and have no means of knowing exactly, how many animal species inhabit our planet. On this point, only conjectures are possible, and although some of these may appear outrageous, they are based on the continuing abundance of the yearly crop of new species. The count of living species is now well over a million. That, however, might be only a modest fraction of the total. French zoologist Lucien Berland (1942) wrote: "On the whole, it does not seem exaggerated to think that there must exist about 5 million species on the globe, and perhaps even more, of which 9/10 are insects." If that is truly the case, then *less than a quarter* of all species presently living have been collected and scientifically described. According to a new calculation by Terry L. Erwin (1982), as many as 30 million arthropod species may exist. If this is correct, we have not yet completed even one thirtieth of the planet's zoological inventory!

What basis is there for such risky estimates? The extrapolation is based, quite straight-forwardly, *on the rate of increase through the years and decades of the number of known species, assuming, quite legitimately, that the rate of discoveries will vary in the future according to a trend already perceptible in past centuries.*

To carry this out (Table 1), one should take into account those general inventories which have been presented in the past, beginning, of course, with that of Linnaeus (1758). In 1817, Cuvier contributed a useful survey of animal species recognized up to that date. These compilations may then be compared to those of Johannes Leunis (1860), inspired in part by the inventories of Wagner, Göppert, and mainly Bronn, presented in 1848 and 1850. We shall then take into account the numerical estimates included in the revised edition of Leunis by Hubert Ludwig (1886), and those of Karl August Möbius (1898), based on the records of the Museum of Natural History in Berlin up to 1896. In the Twentieth Century, we shall note H. S. Pratt's (1912) recapitulation, followed by the painstaking censuses conducted by R. Hesse (1929), carried out with the collaboration of numerous German and foreign specialists, and based on the most careful literature surveys. Finally, we shall incorporate the estimates of Ernst Mayr (1946), which may be compared to his own precise census of the number of bird species.

It is also useful to compare these numerical data sets to more restricted censuses bearing on specific groups of animals. One finds, among the latter, the very old surveys by Henshaw of various classes of vertebrates, by Sharpe of the birds, and the more recent ones by Schultz and Stern of the fishes, by Angel and Cochran of the amphibians, by Guibé and Carr of the reptiles, by Fisher and Peterson of the birds, and by Poole, by Morris, and finally by Honacki, Kinman and Koeppl of the mammals. Henshaw (1912) proposed the following numbers of species: fishes: 12,000; amphibians: 2,200; reptiles: 6,000; birds: 20,000; mammals: 7,000. Schultz and Stern (1948) estimated the number of fish species at 40,000. Angel (1947) enumerated 1,415 species of amphibians, while Cochran (1961) gave a higher estimate, around 3,000. Guibé (1962) spoke of approximately 6,000 species of reptiles, while Carr (1963) gave the more precise count of 5,924. While Sharpe (1909) had recorded 18,937 species of birds, Fisher and Peterson (1964) counted only 8,616. Finally, the early count by Poole (1926) of 10,041 forms of mammals was reduced by Morris (1965) to 4,237 species, and by Honacki *et al.* (1982) to only 4,170.

When all these rows and columns of numbers are presented graphically, a number of striking contradictions appear. The result is not the stepwise

TABLE 1.—Change in the number of registered species in all major groups of animals and in each class of vertebrates during modern times. The data appearing under the names of the various authors do not necessarily refer to the year of publication, but to the period of time concerned. Whereas the numbers given by all other authors are based on countings or estimates (expressed graphically in Figs. 1 and 2), the numbers given by Heuvelmans are based on the graphical expression of their data taken altogether, and occasionally corrected in the light of more recent or more accurate numberings of specific groups (Figs. 3 and 4).

	1758 (Linné)	1817 (Cuvier)	1850 (Leunis)	1850 (Heuvel-mans)	1886 (Leunis & Ludwig)	1896 (Möbius)	1900 (Heuvel-mans)	1911 (Pratt)	1928 (Hesse)	1946 (Mayr)	1950 (Heuvel-mans)	2000 (Heuvel-mans)
Protozoa	3	10	1,400	1,300	4,130	6,000	6,500	8,000	—	15,000	16,000	21,100
Porifera	11	59	528	520	600	1,500	1,700	2,500	4,500	5,000	5,300	6,000
Coelenterata	141	92	3,000	2,700	3,000	3,000	3,400	4,500	9,084	10,000	10,500	12,200
Vermes	47	101	1,270	1,250	6,300	9,000	9,700	12,700	19,650	25,000	26,200	32,000
Mollusca & Brachiopoda	701	965	11,400	10,000	21,320	50,000	64,000	61,000	103,820	88,000	102,400	125,300
Crustacea	101	360	1,500	1,430	5,600	8,150	9,500	16,000	15,500	25,000	26,300	33,400
Arachnida	78	168	3,000	2,700	4,000	20,000	10,200	16,000	28,000	30,000	31,000	34,600
Myriapoda	16	24	700	600	800	3,000	2,400	2,000	8,100	10,000	10,700	13,000
Insecta	1,937	1,393	64,300	62,800	200,000	281,050	300,000	360,000	750,000	750,000	765,000	967,000
Echinodermata	36	143	1,232	1,200	2,370	3,000	3,000	4,000	4,200	4,700	4,800	5,500
Protochordata	—	—	—	—	300	400	600	1,300	1,600	1,700	1,800	2,200
Vertebrata	1,335	2,421	18,567	8,500	24,800	33,500	24,000	34,400	69,319	35,600	40,000	47,700
Pisces	415	1,031	8,000	4,000	9,000	12,000	11,100	13,000	20,000	18,000	20,000	25,600
Amphibia	20	27	400	300	1,000	1,450	1,500	1,400	2,858	1,600	2,600	3,100
Reptilia	162	212	1,100	800	2,500	3,550	3,000	3,500	5,461	3,900	5,000	5,900
Aves	554	765	7,000	2,500	10,000	13,000	6,300	13,000	28,000	8,600	8,700	8,870
Mammalia	184	386	2,067	900	2,300	3,500	2,100	3,500	13,000	3,500	3,700	4,230
Totals	4,406	5,736	106,897	93,000	273,220	418,600	435,000	522,400	1,013,773	1,000,000	1,040,000	1,300,000

increasing trend which one might have logically expected, but a chaotic profile, studded with peaks, looking like the temperature chart of a malarial patient (Figs. 1 and 2).

Why is it, for example, that the number of species in many groups increased abruptly from 1886 to 1896, in just ten years? And, on the contrary, how is it possible that for some other groups—the arachnids and the myriapods, for example—there should be many less species known in 1911 than in 1896? What can possibly explain the dramatic fall in the number of vertebrates between 1928 and 1946?

A number of factors are responsible for these irregularities and apparent absurdities.

First, it was realized that a number of species had been described many times, under different names, which reduced the total number by the elimination of these synonyms. Second, one should note that some inventories (such as Hesse's for all animals, or those of Sharpe for the birds, Poole for the mammals, and Schultz and Stern for the fishes) included *all* known forms, including sub-species as well as species. For mammals as well as for birds, the number of sub-species or geographical races is about three times larger than that of species. Such compilations, in particular that of Hesse, which is responsible for the extremely high peaks of 1928, are to be interpreted as qualitative indicators. Finally, and most importantly, a great number of former species have turned out to be only local varieties or subspecies, and sometimes mere individual variations.

Two opposing tendencies have long divided systematists into two groups: the "splitters" and the "lumpers." Today, it is fortunately the lumpers who have the upper hand. This explains the relatively modest number of species given by Mayr, who took great care to include only so-called "good" species. Given his authority in the matter, one should undoubtedly place the greatest confidence in his results, even though he seems to have exaggerated slightly in the direction of lumping when dealing with vertebrate classes outside his own specialty of ornithology.

A Numerical Estimate of Our Expectations

Taking into account all the data at my disposal—and there are surely others—I have tried to show graphically the gradual enrichment of some of the main groups in the animal kingdom (Fig. 3), and in particular of the various classes of vertebrates (Fig. 4). To ensure uniformity, I have had to follow, on the whole, the older, less detailed classifications in the figures as well as in the tables. This is why such old catch-all categories such as Vermes (worms and vermidians) have been resuscitated; why all chordates other than the vertebrates and the hemichordates have again been lumped into a heterogenous group, the Protochordata; and, finally, why such unrelated

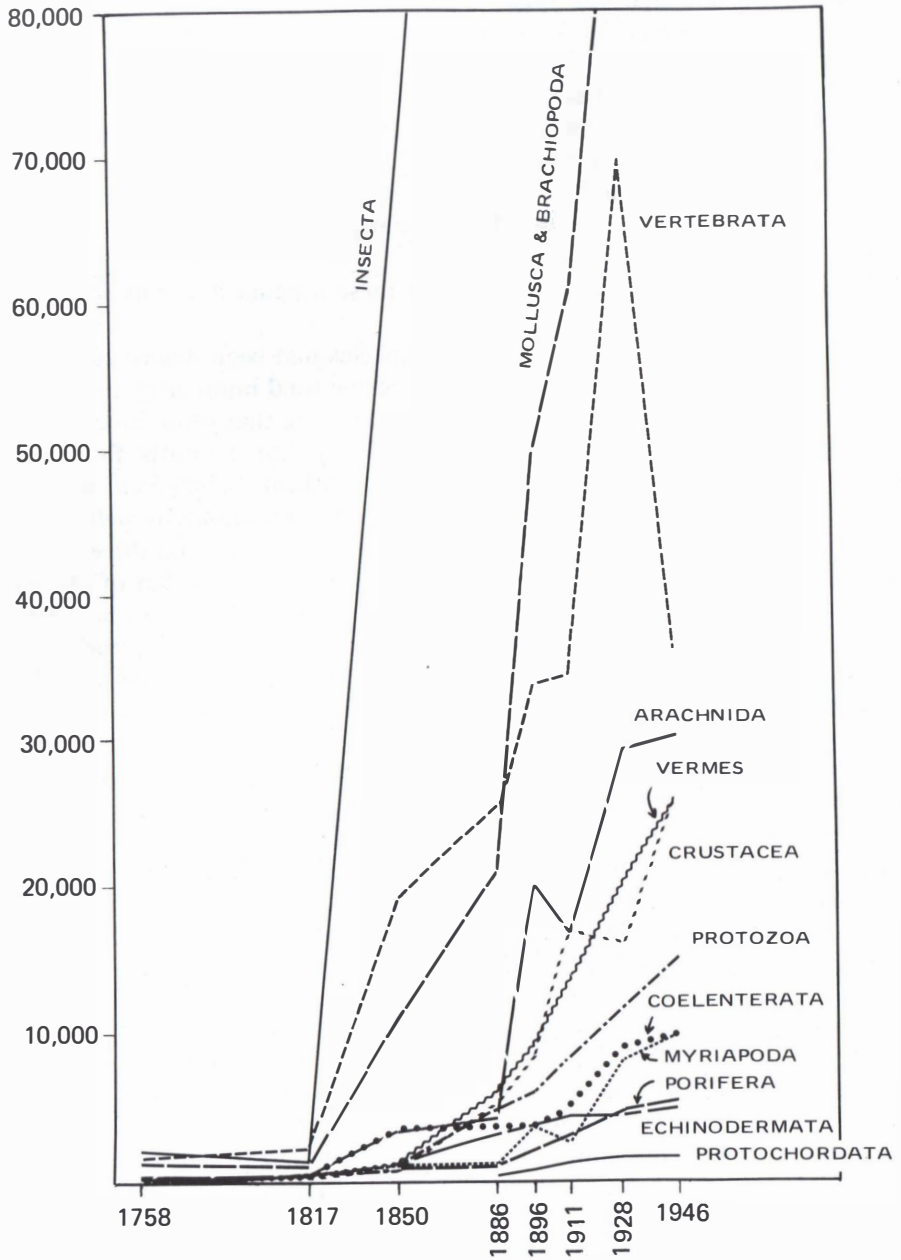

FIG. 1.—Change in the number of registered species in all major groups of animals during modern times according to various authors (see Table 1).

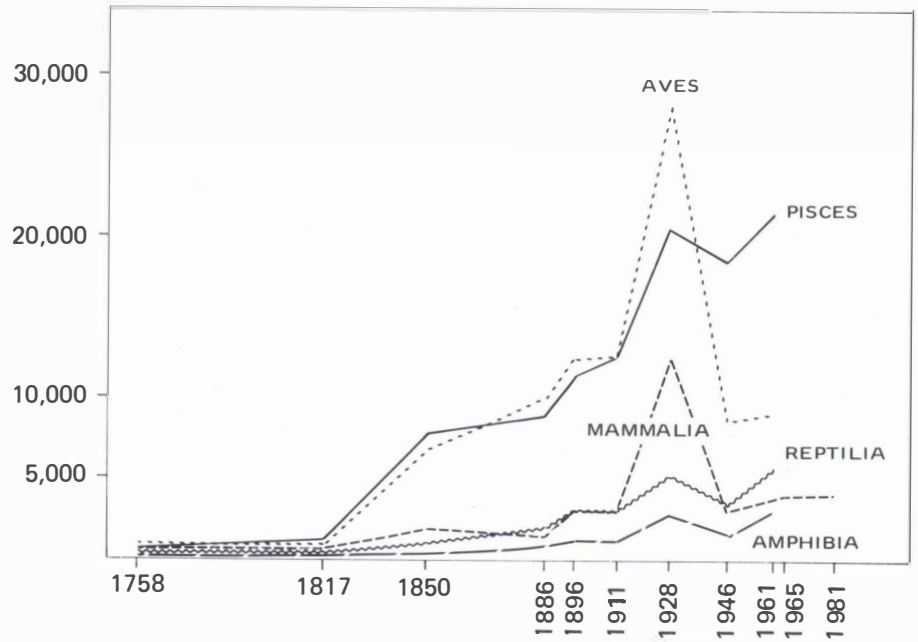

FIG. 2.—Change in the number of registered species in all classes of vertebrates during modern times according to various authors (see Table 1).

animals as molluscs and brachiopods have been grouped together, as they formerly were.

The curves obtained by a judicious smoothing of the original zigzag plots probably represent as faithfully as possible the real increase in "good" species contained in the zoological catalogs of the past two centuries. They should certainly help to determine any real trend from the days of Linnaeus to our own. Continuation of the early Twentieth Century part of the curves should, by extrapolation, yield rather precise estimates on the status of species in 1975 (which it does, on the whole, for those groups which have been the object of an accurate census) and provide useful approximations for the year 2000.

These predictions are of course less precise for curves which rise more steeply, and thus for which the number of species discovered annually is higher. Hence, it is the results on the molluscs, the brachiopods, and especially the insects which must be interpreted most carefully. In tracing the curves, I have always favored a more conservative approach, as shall become apparent below.

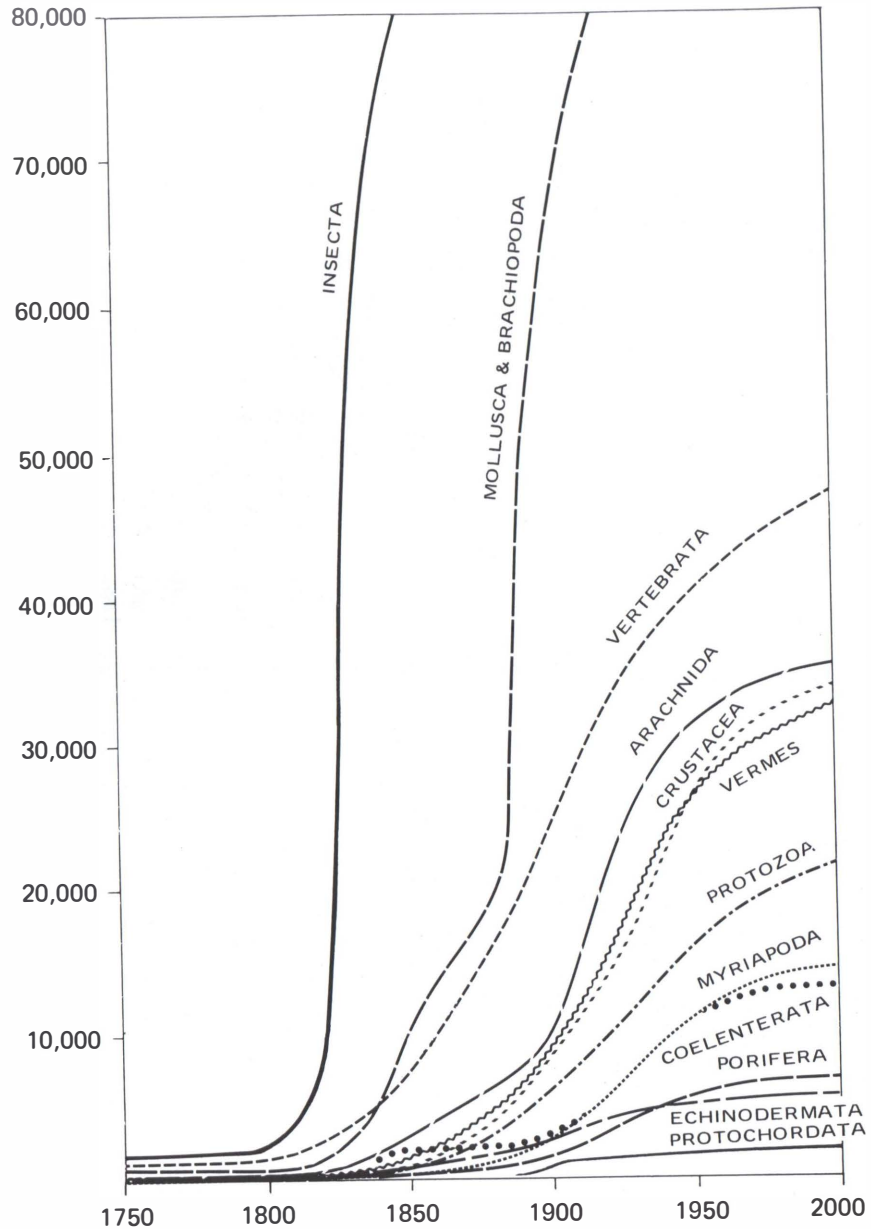

FIG. 3.—Increase in the number of known species in all major groups of animals during modern times, as proposed by the author.

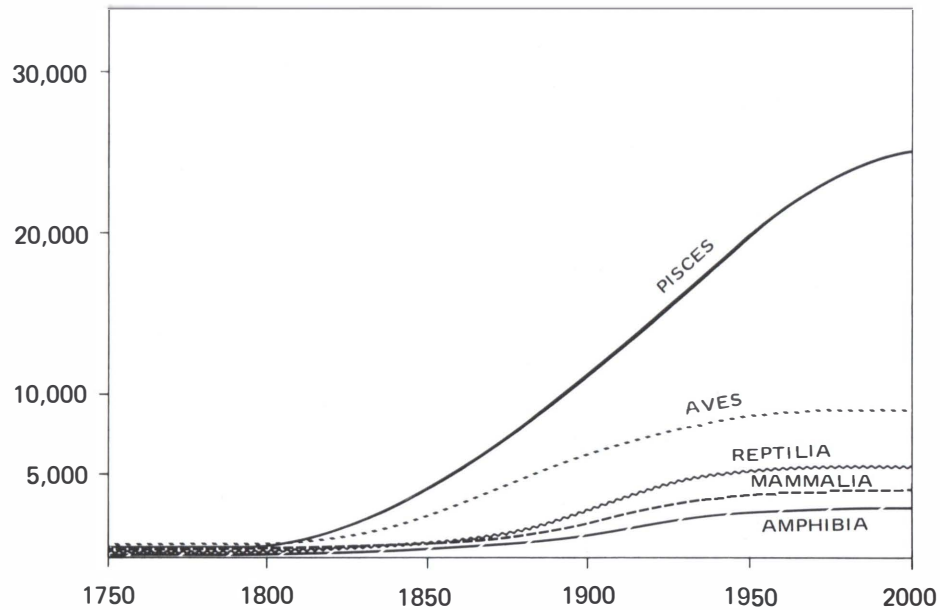

FIG. 4.—Increase in the number of known species in all classes of vertebrates during modern times, as proposed by the author.

Numerical estimates taken from the smoothed curves for the years 1850, 1900, 1950 and 2000 have been entered in Table 1 for the sake of comparison of these personal estimates with earlier results.

To determine the rate of increase of the number of known species in each group of organisms, one takes differences between data half a century apart. Dividing by 50 then yields the average number of species described each year in each half century, or, equivalently, assuming that the rate of discovery does not vary too quickly, the number of species discovered each year at the mid-point of each period, i.e., in 1875, 1925 and 1975 (Table 2).

The final result of all these calculations is that the number of animal species increased by nearly 350,000 during the second half of the last century and by about 600,000 during the first half of the present century; it should increase again by at least 250,000 (from our conservative point of view) during the second half of this century. The inventory of the animal kingdom has been enriched annually, on the average, by nearly 7,000 new species between 1850 and 1900, and by about 12,000 between 1900 and 1950; this gradual increase will continue at about 5,000 per year for the period 1950–2000. The insects contribute the majority of the annual figures: nearly 4,750

TABLE 2.—Rate of discovery of new species of animals in all major groups and in each class of vertebrates during modern times. As the average number of species discovered per year during each half of a century corresponds approximately to the number discovered about the middle of these periods, the relevant figures have accordingly been situated in 1875, 1925 and 1975 in Fig. 5.

	Between 1850–1900	Average per annum	Between 1900–1950	Average per annum	Between 1950–2000	Average per annum
Protozoa	5,200	104	9,500	190	5,100	102
Porifera	1,180	23.6	3,600	72	700	14
Coelenterata	700	14	7,100	142	1,700	34
Vermes	8,450	169	16,500	330	5,800	116
Mollusca & Brachiopoda	54,000	1,080	38,400	768	22,900	458
Crustacea	8,070	161.4	16,800	336	7,100	142
Arachnida	7,500	150	20,800	416	3,600	72
Myriapoda	1,800	36	8,300	166	2,300	46
Insecta	237,200	4,744	465,000	9,300	202,000	4,040
Echinodermata	1,800	36	1,800	36	700	14
Protochordata	600	12	1,200	24	400	8
Vertebrata	15,500	310	16,000	320	7,700	154
Pisces	7,100	142	8,900	178	5,600	112
Amphibia	1,200	24	1,100	22	500	10
Reptilia	2,200	44	2,000	40	900	18
Aves	3,800	76	2,400	48	170	3.4
Mammalia	1,200	24	1,600	32	530	10.6
Totals	342,000	6,840	605,000	12,100	260,000	5,200

a year during the second half of the Nineteenth Century, more than 9,000 for the first half of the Twentieth Century, and at least 4,000 during its second half.

This is where the conservative nature of my estimates is confirmed, in the light of those offered by others. Edward Chapin (Anonymous 1952) evaluated at about 5,000 the number of new insect species discovered each year; Maurice Burton (1961) gave a higher estimate, 6,000, and Joan Arehart-Treichel (1978), 7,000.

An analysis of the numerical results of Table 2 leads to the following conclusions.

First, that it is during the first half of our century that the rate of discovery of new species reached its peak in the majority of phyla of the animal kingdom. The only exception to this rule is the heterogeneous group of molluscs and brachiopods, where the rate of discovery peaked in the last century and has since continuously declined.

The rate of discovery of new species has dropped, more or less abruptly, in all phyla. This deceleration is most noticeable nowadays, following the former period of abundant discoveries during the first half of this century.

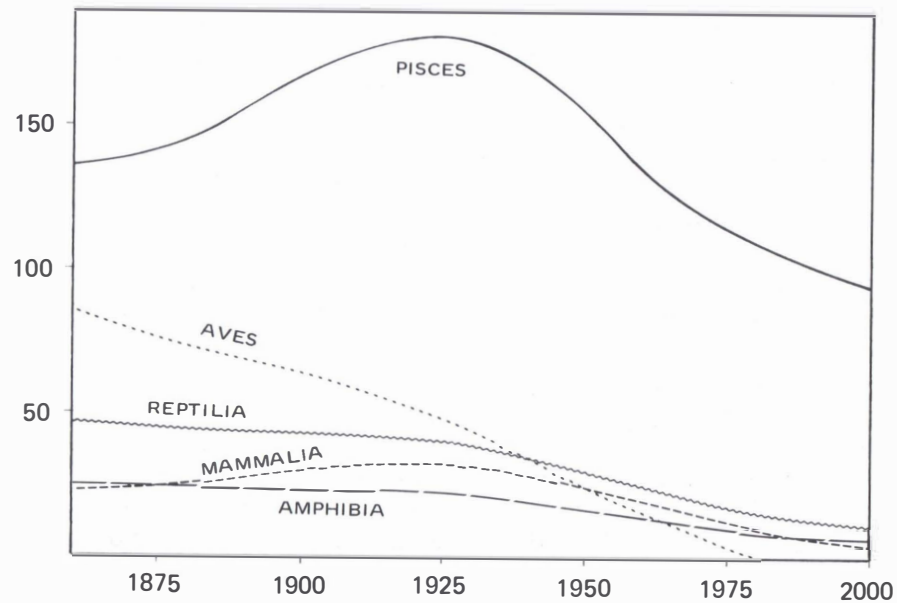

FIG. 5.—Rate of discovery of new species in all classes of vertebrates during modern times (see Table 2).

This is of course not unexpected: the faster the rate of discovery, the more rapid the decrease of the remaining, yet-to-be-discovered stock.

What has happened for the various classes of vertebrates should be of particular interest to cryptozoologists. Quite recently, in the mid 1970's, there were discovered, each year, around 112 new species of fishes, 18 new species of reptiles, about ten new species of amphibians, the same number of mammals, and 3 or 4 new species of birds. Here, too, the rate of discovery has slowed down at different rates in the various classes. A graphical presentation of the data of Table 2 gives a more exact idea of this variety (Fig. 5).

One may note from Fig. 5 that the deceleration of the annual discovery rate had already begun in the last century for most classes of vertebrates, but not for the fishes, well hidden in the waters, particularly those of the marine environment, nor for the mammals, more elusive than had been imagined, perhaps because of their higher intelligence. Today, the rate of discovery is slowing down only very gradually for reptiles and amphibians, of which one should still expect to discover 12 and 7 species a year, respectively, by the year 2000. At the same time, it should decrease much

more rapidly for the mammals, with only 3 or 4 new species a year by the end of the century, and extremely rapidly for the fishes, with only about 90 species a year by then, which is *relatively* little given the number of species in that class. It is for the birds that the decline in the rhythm of discovery is most dramatic; one can even predict that the inventory of that class will have been practically completed between 1985 and 1990. This is, of course, quite a logical expectation, given the generally conspicuous nature of these avians.

This study is founded on quite controversial premises, about which there exists no general consensus, and it is to be expected that the numerical conclusions which follow are subject to a certain lack of accuracy. Our essential aim has been to obtain orders of magnitude and to make comparisons.

Bearing this in mind, and barring unforeseen developments, the main thrust of our conclusions is that one may entertain high hopes for future discoveries, providing full justification for cryptozoological research. By its very nature, such research should accelerate noticeably the rate of discovery of animals of medium to large dimensions. Most importantly, it should make it possible to discover many of them before they disappear without our even having noticed them under the pressure of the irreversible destruction of many parts of the biosphere.

References Cited

Angel, Fernand
1947 *Vie et moeurs des Amphibiens.* Paris: Payot.

Anonymous
1952 Thousands of New Life Forms Discovered Annually. *Science News Letter,* Vol. 61: 168.

Arehart-Treichel, Joan
1978 A Day in the Life of the Sole Insect of the Sea. *Science News Letter,* Vol. 113: 190.

Belon, Pierre
1555 *La Nature et Diversité des Poissons.* Paris: C. Estienne.

Berland, Lucien
1942 *Les Insectes et l'Homme.* Paris: Presses Universitaires de France.

Bronn, Heinrich Georg
1859–97 *Die Klassen und Ordnungen des Thier-Reichs.* Leipzig-Heidelberg.

Burton, Maurice
1961 How Many Species of Animals Are There? *Daily Telegraph* (July 7).

Carr, Archie
1963 *The Reptiles.* New York: Time, Inc.

Cochran, Doris M.
1961 *Living Amphibians of the World.* New York: Hanover House.

Cuvier, Georges
1817 *Le Règne Animal Distribué d'après son Organisation.* Paris: Déterville.

Delage, Yves, and Edgard Hérouard
1896–1903 *Traité de Zoologie Concrète.* Paris: Schleicher Fréres.

Erwin, Terry L.
1982 Tropical Forests: Their Richness in Coleoptera and Other Arthropod Species. *The Coleopterists Bulletin,* Vol. 36(1): 74–75.

Fisher, James, and Roger Tory Peterson
1964 *The World of Birds.* London: Macdonald.

Grassé, Pierre-Paul
1968 *La Vie des Animaux.* Vol. I. Paris: Larousse.

Guibé, Jean
1962 *Les Reptiles.* Paris: Presses Universitaires de France.

Henshaw, H. W.
1912 Number of Species of Living Vertebrates. *Science,* Vol. 36: 317–18.

Hesse, R.
1929 Bericht uber das "Tierreich." *Sitzungsber. Preuss. Akad. Wiss.,* Berlin: XL–XLIV.

Heuvelmans, Bernard
1955 *Sur la Piste des Bêtes Ignorées.* Vol. I. Paris: Plon. (Repr. Paris: Francois Beauval; Geneva: Famot.)

Heuvelmans, Bernard
1958 *On the Track of Unknown Animals.* London: Rupert Hart-Davis; New York: Hill & Wang.

Heuvelmans, Bernard
1969 Note Préliminaire sur un Spécimen Conservé dans la Glace, d'une Forme Encore Inconnue d'Hominidé Vivant: *Homo pongoides. Bulletin de l'Institut Royal des Sciences Naturelles de Belgique,* Vol. 45(4): 1–24.

Honacki, James H., Kenneth E. Kinman, and James W. Koeppl
1982 *Mammal Species of the World.* Lawrence, Kansas: Allen Press/Association of Systematics Collections.

Hyman, Libbie Henrietta
1962 "Zoology," in *Encyclopedia Britannica*: Chicago-London-Toronto: Vol. 23.

Lamarck, Jean-Baptiste de Monet, chevalier de
1806 *Recherches sur l'Organisation des Corps Vivants.* Paris: Chez l'Auteur au Muséum d'Histoire Naturelle.

Lamarck, Jean-Baptiste de Monet, chevalier de
1809 *Philosophie Zoologique, au Exposition des Considérations Relatives a l'Histoire Naturelle des Animaux.* Paris: Dentu.

Leunis, Johannes
1860 *Synopsis der drei Naturreiche: Zoologie.* Hannover: Hahn: Zweite Auflage.

Leunis, Johannes u. Hubert Ludwig
1883–86 *Synopsis der Thierkunde.* Hannover: Hahn: Dritte Auflage: II.

Linnaeus, Carolus
1758 *Systema Naturae per Regna tria Naturae.* Holmiae: Impensis L. Salvii: Editio decima.

Mayr, Ernst
1935 How Many Birds Are Known? *Proceedings of the Linnean Society,* Vol. 45–46: 19–24.

Mayr, Ernst
1946 The Number of Species of Birds. *Auk,* Vol. 63: 64–69.

Möbius, Karl August
1898 Ueber den Umfang und die Einrichtung des Zoologischen Museums zu Berlin. *Sitzungsber. Preuss. Akad. Wiss.,* Berlin.

Morris, Desmond
1965 *The Mammals: A Guide to the Living Species.* London: Hodder & Stoughton.

Poole, Arthur J.
1926 The Number of Forms of Recent Mammals. *Journal of Mammalogy,* Vol. 7: 134–35.

Pratt, H. S.
1912 Number of Known Species of Animals. *Science,* Vol. 35: 467–68.
Schultz, Leonard P., and Edith M. Stern
1948 *The Ways of Fishes.* New York: Van Nostrand.
Sharpe, Richard Bowdler
1909 *Hand-List of the Genera and Species of Birds in the British Museum.* London: British Museum, Vol. 5: XII.
Taylor, Leighton R., L. J. V. Compagno, and Paul J. Struhsaker
1983 Megamouth—A New Species, Genus, and Family of Lamnoid Shark (*Megachasma pelagios,* Family Megachasmidae) from the Hawaiian Islands. *Proceedings of the California Academy of Sciences,* Vol. 43(8): 87–110.
Wetzel, Ralph M., Robert E. Dubos, Robert L. Martin, and Philip Myers
1975 *Catagonus,* An "Extinct" Peccary, Alive in Paraguay. *Science,* Vol. 189: 379–80.